IMPROVING TRANSPORTATION, PRICING, LAND USE, AIR QUALITY (TPLUAQ) MODELS

BY MICHAEL REPLOGLE
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ABSTRACT

This paper provides a critical overview of current practices in metropolitan transportation modeling for air quality planning in the U.S., based on a decade of experience in managing the development of new models in the Washington, DC region. The paper suggests ways that these practices might be improved, given the current state of professional practice.

Many aspects of the current standard practice in transportation modeling are inadequate to meet the challenges of transportation, land use, and air quality planning in the 1990s. There has been relatively little innovation in travel demand analysis technique over the past two decades, despite massive advances in capabilities for computer analysis, information systems, and automated data collection. Work needs to proceed on several parallel tracks -- (1) immediate quick fixes to support the next round of air quality conformity analysis, (2) incremental improvements to the 4-step modeling process, and (3) development of new methods, such as activity-based travel demand microsimulation techniques and real-time traffic network simulations which could support refined emissions models based on real driving cycles.

The transportation models in widespread use were mostly developed for the narrow purpose of highway engineering, not air quality and long-range land use/transportation planning. To meet these latter purposes, models must be sensitive to many more factors. Demographic sensitivity is needed to reflect life-cycle stages and aging of the population and of neighborhood demographic mixes. Travel time needs to be treated more consistently and rigorously in travel demand estimation, including the effects of congestion and capacity changes on spatial and temporal trip distribution and mode choice. Trip distribution needs to be done separately for different travel modes to properly reflect the effects of changes in non-automobile accessibility. The effect of transportation investments on land use changes needs to be accounted for. More detailed highway network simulation, separating link and intersection capacity and delay, is needed to improve the simulation of travel times. Smaller and more detailed transportation analysis zones, especially in areas where there is potential for significant use of non-automobile modes, can facilitate improved modeling of transit access and short trips, where walking and cycling can be important factors. Factors influencing travel behavior which exhibit greater variance within transportation analysis zones than between zones have not been well accounted for in conventional modeling practice. These include the pedestrian proximity of jobs and housing to transit

stops and to neighborhood retail services, the quality of the pedestrian and bicycle environment, the cost and convenience of parking , and other urban design factors. Geographic Information Systems (GIS) offer an affordable framework to measure and account for these interactions and should thus be integrated with travel models.

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I. NEW REQUIREMENTS FOR TRANSPORTATION MODELING

The 1990 Clean Air Act Amendments (CAA) require analysis of transportation programs for conformity with air quality implementation plans in regions that are in non-compliance with clean air standards. To examine conformity of transportation plans, Metropolitan Planning Organizations (MPOs) and other organizations generally need to rely on computer models that simulate the interaction between transportation and land use. Outputs from these models are in turn used with air pollution emission models to evaluate the impact of various policies and investments on air quality.

The state of the practice in transportation modeling for air quality planning varies widely across the U.S., but there is growing consensus among transportation professionals that current practices and capabilities for such analysis is weak and in need of substantial improvement. Many MPOs, including those in some of the largest U.S. cities, lack any operational four-step regional transportation model and are using very crude trends analysis techniques for air quality analysis. In many other MPOs, the models currently available were developed many years before on data sets which may not have been updated for two decades or more. These models typically were developed for highway planning, with no attempt to consider social or economic changes, alternative future scenarios, or significant environmental constraints.

While there are a number of different approaches that can be taken by MPOs and DOTs to assess TPLUAQ relationships at a metropolitan level, with few exceptions, the classic four-step modeling process, in use since the early 1960s for highway and transit planning, remains the standard technique. Several recent conferences and reports sponsored by FHWA and the US EPA have identified many of the shortcomings of this approach as applied by transportation agencies around the U.S., discussing many of the requirements for developing improved models.[1]

A shortage of resources has hampered transportation, land use, pricing, and air quality (TPLUAQ) data collection, analysis, and model development efforts even in the organizations doing the most advanced analysis today in America. Thus, even the best current practices are unsatisfactory in their sensitivity to a number of important factors that influence travel demand and transportation system performance. In many areas, new data collection efforts will be needed to support development of truly adequate models for air quality analysis. Table 1 suggests some of the key types of data which should be collected as soon as possible in most regions to develop enhanced modeling systems. Such data collection should be a part of ISTEA-mandated management systems related to congestion, goods movement, transit and other elements.

Table 1: Data Needs for Enhanced Model Development
• *Panel Surveys*. Initiation of household and employer-based panel surveys and other surveys to monitor changes in travel behavior and travel costs and subsidies over time, • *Traffic Counts.* Development of regional traffic count inventories, with adequate peak hour, peak period, and 24-hour counts to support improved emissions inventories and TPLUAQ model calibration, • *Travel Time & Delay*. Travel time and delay studies to provide the basis for improved calibration of emissions inventories and TPLUAQ models, • *Transport Supply Inventories*. Inventories of transportation supply, with information on road widths, number of lanes, presence of medians, intersection configurations, transit services, including transit stop locations and service frequency, parking inventories, including park-and-ride lots, location and character of sidewalks and bicycle paths and lanes, availability of secure bicycle parking spaces at transit stops, and other factors. • *Pricing Data.* Development of transportation pricing databases, reflecting the share of employees getting free parking at individual sites or within compact zones, the cost of short and long term commercial parking, HOV pricing incentives and other commuter subsidies, as well as transit costs on an origin-destination basis (if appropriate by mode), • *Goods Movement Data.* Truck and goods movement data and surveys to support metropolitan goods movement strategy planning and emissions evaluation, • *Special Generators*. Studies of special generators, such as airports, large hospitals, and universities, to support their better consideration in the metropolitan TPLUAQ analysis process. • *Land Development Inventories*. Inventories of housing and employment location by type, including current land use, approved but unbuilt development, zoning ceilings, and forecasts in 5 year increments for more and less clustered or sprawled development patterns, dependent on transportation investment and policy and possible zoning changes, development of historical inventories of changes in land use and transport supply and price over recent decades to support development of land use forecasting models and the validation of long-range

applications of TPLUAQ models.

Far greater resources will need to be expended on data collection, analysis, and model development. Fortunately, ISTEA provided increased funding for metropolitan planning and provides states and MPOs with the flexibility to use other ISTEA fund categories for such activities. Expeditious implementation of Transportation Control Measures and other requirements of the Clean Air Act indeed necessitates sharply increased expenditures on metropolitan planning activities related to mobile source emissions analysis and transportation related air quality planning. While lack of resources may have been a plausible excuse for past model and data collection deficiencies, under the expanded funding flexibility of ISTEA, this rationale appears to be no longer valid.

Work on improving MPO and state DOT transportation models used for air quality analysis needs to proceed on several parallel tracks -- (1) immediate quick fixes to support the next round of air quality conformity analysis, (2) incremental improvements to the 4-step modeling process, and (3) development of new methods, such as activity-based travel demand microsimulation techniques and real-time traffic network simulations which could support refined emissions models based on real driving cycles.

The first of these tracks requires highly varied responses to local circumstances, depending on the particular strengths and weaknesses of existing models, data sets, and planning needs. Given the poor state of the practice in many regions and the time required to improve transportation, pricing, land use, and air quality (TPLUAQ) monitoring, analysis, and forecasting systems, many regions will need to devise ways of reflecting better policy sensitivity to key factors while new data and more advanced systems for analysis are under development.

This paper focuses primarily on the common improvements that will be needed if the four-step process is to display appropriate policy sensitivity for long-range transportation/land use air quality conformity analysis. Without such improvements, many effective strategies for meeting the goals of the CAA and providing more cost-effective transportation and community systems will not be identified or considered in America's metropolitan regions. Earnest efforts to improve analysis methods can be expected to reduce the likelihood of conflict and litigation with citizen and environmental groups over issues of improper modeling procedures and inadequately documented assumptions.

Many of the improvements in the four-step process recommended in this paper will require the development of more disaggregate descriptors of urban patterns and smaller-scale transportation system elements. It is likely that these refined data elements will be relevant to the estimation of more advanced activity-based microsimulation models, helping such models reflect important factors which influence travel behavior and transportation system performance.

II. IMPROVING TRIP GENERATION MODELS

Trip generation models are used to estimate the number of trips that will be associated with a given set of land uses. These affect the ability of models to estimate for different transportation and land use policies the number of vehicle trip starts, which account for the majority of mobile source emissions in most metropolitan regions. There are several major problems in the current policy sensitivity and performance of trip generation models in use by U.S. MPOs today:

1. Models frequently focus on vehicle trip generation, rather than person trip generation, making the entire model chain insensitive to the potential for short trips to switch between motorized and non-motorized modes of transport.
2. Models lack sensitivity to demographic variation and changing urban structure and rely too heavily on geographic-specific coefficients in model calibration which mask underlying reasons for spatial variation in trip generation.
3. Models are generally incapable of representing trip chains and the interdependency between trips made by various purposes and modes to fulfill activity needs, making it likely that models will overestimate the reductions in trip starts associated with work-trip oriented TCMs.
4. Models frequently normalize trip attractions to match trip productions after application of trip generation models, based on the assertion that there is more confidence in the home-based productions models than the work-based attractions models. However, unless balanced by appropriate changes in external trip productions at the edge of the modeled region, this procedure results in underestimating the effects of imbalanced regional job growth relative to regional housing growth, and can significantly underestimate future congestion and emissions.

1. Person Trips Not Vehicle Trips. In many cases, current MPO transportation models estimate only vehicle trips for non-work trip purposes, or even for work trip purposes, ignoring trips made by walking or bicycling. Trip rates per household are generally noted to be higher in suburban areas than in urban centers, in part because many newer suburbs have been developed in a manner that reduces current opportunities to satisfy activity needs by making short trips on foot or by bicycle. Vehicle-trip oriented models are not able to reflect the potential for alternative transportation and land use strategies or Transportation Control Measures (TCMs) to divert short automobile trips to non-motorized modes, nor can they reflect the potential for certain automobile-oriented transportation and land use policies to increase automobile dependence for short trips in formerly pedestrian friendly communities.

Agencies which have such vehicle-trip oriented models can adjust the vehicle trip generation rates for an area upward or downward as a quick-fix way to reflect alternative transportation and land use strategies, as was done in a recent study for Middlesex-Somerset-Mercer Counties in New Jersey carried out by Bruce Douglas. However, this approach can produce only a first order adjustment of demand forecasts and is difficult to back up empirically. It is thus only a short-term response to model deficiencies.

It is preferable to re-estimate trip generation models to simulate person trips, which can then be distributed by time of day and destination, and apportioned to various motorized and non-motorized modes. In that way, changes in policies which might shift the share of daily activities which can be satisfied with short trips or which might make walking and cycling more or less relatively attractive, safe, or cost-effective can be explicitly modeled for their potential to reduce vehicle trips. This is of particular importance since vehicle trip start emissions, not running emissions, account for the majority and a growing share of total mobile source air pollution emissions in most metropolitan areas.

2. Model Sensitivity to Changing Demographics and Urban Structure. Trip generation models in use by U.S. MPOs frequently estimate trip generation for three to six trip purposes by multiplying the number of households by a set of purpose-specific coefficients. Typically, different sets of coefficients are used in central city areas, inner suburbs, and outer suburbs. The use of such geographic-specific model coefficients masks the underlying reasons for variations in travel behavior, such as differences in household size, income, age, vehicle ownership, accessibility by different modes. While these geographic-specific coefficients may match observed travel behavior for the calibration year, they will likely be unstable over time.

When new developments open, they often exhibit far different demographic characteristics than a decade or two later, as the population ages, household size changes, and household life-cycle diversity increases. Similarly, employment areas undergo significant changes in trip generation rates as building fill up, turn over, decline, and possibly undergo renewal or changes in use patterns. Employee densities per square foot of floor space may exhibit substantial variation, depending on proximity to transit stations, building age, and other factors. For all of these reasons, the use of fixed trip generation rates that are assigned by area should be avoided. A number of factors that should be considered in developing new trip generation models are shown in Table 2.

Table 2: Factors to Consider in Trip Generation
Trip generation is logically related to the number of jobs and households, but may also be influenced by –   • dwelling unit type • household size • building utilization factors (number of employees per square foot of space by type) • labor force participation • age distribution of persons • household income • automobile ownership/availability • share of walk, bicycle, and transit trips • composite accessibility factors • pedestrian proximity to convenience retail

Similarly, metropolitan structure changes over time. The multi-nucleation of metropolitan areas makes the use of "Central Business District" (CBD) binary variables increasingly suspect, as these variables typically mask variations in regional accessibility and pedestrian friendliness. CBD binary variables, however, are common, even among some of the most otherwise policy-sensitive MPO travel demand models in trip generation, distribution, and mode choice analysis. CBD variables in models should be replaced by other factors relating to employment density, share of access to regional housing and employment, and pedestrian friendliness or other urban design factors. In this way, the effects captured by CBD binary variable can be reflected more explicitly and more incrementally in other emerging primary CBDs of multi-centered regions.

3. Sensitivity to Trip Chaining. In metropolitan areas across the U.S. over the past several decades, there has been a sharp decline in the share of work trips compared to non-work trips. Much of this change can be attributed to growth in trip chaining. What were formerly trips directly from home to work have become trips from home to day care center to work, or work to shop to home.

Trip chaining, or the linking of one trip to another, is difficult to accomplish within the fragmented four-step model process. However, because trip chaining is a growing phenomena especially in more automobile-oriented suburban areas, has a major influence on the number of trip starts and the fraction of trips made in a cold start mode, and may vary significantly in frequency under different transportation and land use scenarios, it is important to consider in air quality modeling.

Research by the Montgomery County Planning Department, using a recent household travel survey for the Washington, DC region, shows that trip chaining is far more common among those living and working in the automobile-oriented suburbs than among those living or working in denser mixed use centers. While those in the latter areas are able to accomplish more errands on foot at lunch time or after work, and are thus often less restrained from using transit for commuting, those in the former areas are often made automobile-dependent by the need to run errands by car during the day. Proximity thus may have a significant impact on trip generation, distribution and mode choice. Work trip length is also a factor. Those who make chained work trips overwhelmingly drive cars to make those trips.

MPOs developing new trip generation, distribution, and mode choice models should seek to makes these more sensitive to trip chaining. This may be partially accomplished within the "four-step" process by separately generating linked and non-linked work trips by time of day, along with work-based and other non-home-based non-work trips, as has been done in Montgomery County, Maryland. Different trip distribution and mode choice model coefficients can then be applied to linked vs. non-linked trips, with shorter average trip lengths and much greater automobile dependence for linked trips than for non-linked trips.

More holistic approaches to trip chaining, however, require new types of model structures which consider personal and household activity patterns and needs, as well as the incomplete information people have about possible destinations where their needs can be satisfied, the proximity of those places to other destinations, and the modes available to reach them. These new types of model structures are being explored in work by Ruyichi Kitamura and others on activity-based microsimulation models.

4. The Need to Consider Job/Housing Balance in Land Use and External Production/Attraction Forecasts. Conventional regional transportation models generate trip attractions and productions and normalize one to the other (usually forcing the number of employment attractions to equal the number of household productions for work trips, for example). At the same time, regional models require the specification of trip productions and attractions and through trips at the external boundary of the modeled region. It is important to ensure consistency over time in the treatment of these various sources of trip productions and attractions.

In some regional models, this normalization has hidden growing imbalances in the amount of forecast housing available for workers. This imbalance can be satisfied in only one of two ways -- by importing more workers into the modeled region from beyond the external boundaries for the region, or by assuming that some of the forecast employment is not realized. Normalization presumes the latter and that the unfilled jobs are proportionally distributed throughout the modeled region.

It is desirable to account for regional imbalances in job and housing growth over time in the specification of external productions and attractions, and an end to the practice of normalization of productions and attractions. Where such normalization factors are small, they are of little consequence, but where they grow over time, they may mask serious problems in the land use forecasts, unless explicitly compensated for by matched increases in forecast growth in external trip productions and attractions. In some regions, such as the Washington, DC, area, housing forecasts and zoning potential are inadequate to house the forecast number of workers. This implies that either forecast jobs will go unfilled or more workers will commute into the region from housing outside of the modeled region. The latter situation would require adjusting external trip production and attraction forecasts or extending the modeled region to the entire future commuter-shed. Alternatively, the land use forecasts for the modeled region require new assumptions.

External trip productions and attractions should be sensitive to changes in land use and transportation forecasts. Improvements to roads, HOV facilities, or rail services that extend to near the edge or beyond the modeled region should be accounted for by appropriate changes to external trip productions and attractions at the affected external stations. Similarly, major changes in forecast employment in areas near the edges of the modeled region should be accompanied by significant changes in external productions and attractions. These changes are ones which can and should be accounted for immediately in the application of existing model systems, requiring mostly inspection of the logical consistency of model inputs and outputs between base year and future scenarios, along with application of good planning judgment.

III. Improving Trip Distribution Models

There are several major problems with trip distribution models as typically used in MPO and state DOT models in the U.S. These have major implications for the findings of transportation/air quality conformity analysis and require immediate corrective action.

5. Models frequently ignore the effects of traffic congestion and changes in transportation capacity on trip distribution. This likely results in an overestimation of congestion and emissions in "no-build"

analyses and many future year forecasts and an underestimation of induced travel demand and emissions in "build" analyses.

6. Even when transportation system performance is considered in trip distribution, models usually rely only on highway travel times to estimate changes in trip distribution, rather than considering the effects of changes in accessibility by public transportation or non-motorized modes. As a result, the models likely underestimate the long-term potential emissions reductions that could result from major transit investments, traffic calming and central area traffic restraint policies, diversion of highway investments into alternative modes, and major improvement of pedestrian and bicycle friendliness, including increased local heterogenity of land use mix.
7. Models often consider temporal trip distribution of trips by time of day to be fixed, ignoring the effects of traffic congestion or changes in capacity or demographics on departure time choice. This likely results in an overestimation of congestion and emissions in "no-build" analyses and many future year forecasts and an underestimation of induced travel demand and emissions in "build" analyses.

1. Need for internally consistent treatment of travel times in models. Many MPOs and state DOTs assume a static default set of travel times between origins and destinations for future year spatial trip distribution. This makes the models insensitive to the effect of major highway widenings on the number and length of trips made within the affected corridor, thus leading to frequent overestimation of travel time savings, congestion reduction, and emissions reduction associated with highway capacity expansion. This also makes the models insensitive to the likely dampening effect that increased corridor traffic congestion may have on the number of trips and length of trips made within a corridor subject to growth in land use intensity without accompanying new highway capacity expansion, thus overestimating emissions associated with "no-build" analyses. Since most metropolitan regions are forecasting significant growth in traffic congestion in the next decade even under their most capacity-expansive forecasts, trip distribution models insensitive to congestion and capacity expansion are likely overestimating future mobile source emissions relative to more internally consistent models.

A fundamental element of good transportation modeling practice should be the internally consistent treatment of travel times for destination choice, departure time choice, mode choice, and multi-modal network assignment. This is already accomplished by several of the better metropolitan transportation models.

This should be accomplished whenever possible through an equilibrium process, rather than through recursive iteration. In congested networks, recursion often does not provide satisfactory closure, exhibiting features of a chaotic system. Montgomery County, Maryland, has very recently developed an equilibrium multi-modal destination and departure time choice/mode choice/network assignment algorithm implemented using EMME/2's equilibrium assignment process.[2]

2. Integrating Multi-Modal Factors into Spatial and Temporal Trip Distribution. Even when trip distribution reflects the effects of congestion or highway capacity expansion, travel time changes, MPO and state DOT models tend to consider only highway travel times in this feedback process. While this is reasonable for short-term forecasts in highly automobile dependent areas, it masks important factors that can shape metropolitan mobility patterns in areas where alternatives to the automobile account or might account in the future for a significant share of trips. Thus, it is important for all regions to develop multi-modal trip distribution models for long-range planning if multi-modalism is to even be considered as a long-term option for regional development.

To ensure sensitivity to the full range of policy choices for long-term analysis of trip distribution, both spatial and temporal, a number of non-traditional factors should be considered for inclusion in the analytic process. Automobile and transit travel time and travel cost are key elements, but traveler choice appears to be influenced also by the quality of the pedestrian (and bicycle) environment.

To the extent that modes other than the automobile play or might play a significant role in travel for an area, including as transit access modes, consideration should be given to the travel time, cost, and "level of service" of these non-automobile modes in the travel demand analysis process. Choice-based logit models offer a suitable framework for statistical evaluation of significance of these factors. Table 3 illustrates some of the types of factors which should be considered in developing more multi-modal spatial and temporal trip distribution choice models.

Table 3: Factors to Consider in New Multi-Modal Spatial and Temporal Trip Distribution Choice Models
• travel time and cost by automobile, walk-to-transit, drive-to-transit, bicycle, and walk • proximity of jobs and housing to transit (% within 1/4 mile of bus stops and 1/2 mile of rail stations; % within 1-1/2 miles of rail stations for potential bicycle access) • proximity of jobs and housing to services (% within walking distance of shopping centers) • household income • household automobile ownership/availability • automobile network density and quality factors (congested-to-freeflow travel time by auto, parking scarcity and auto egress time at destination) • pedestrian network density and quality factors (e.g. the ratio of sidewalk miles to street miles, connectivity of pedestrian facilities, indices related to the difficulty of crossing streets, streetscape continuity and frontage factors, proximity to pedestrian-only streets) • bicycle network density and quality factors (e.g. the ratio of bikeway miles to street miles, bicycle friendliness index of streets, bicycle parking availability/security factor, street crossing difficulty factor) • number of jobs/households by zone (destination choice) • congested-to-freeflow travel time by auto (departure time choice)

3. Departure Time Choice Representation. Many MPO and state DOT models use fixed factors for road links to convert simulated daily traffic volumes to peak or off-peak hour volumes. Some instead

factor daily trip tables to produce travel demand trip tables by time of day, but often use fixed coefficients estimated from a base year to perform this factoring. Both of these approaches are insensitive to important factors that influence the time-of-day of travel.
Instead, it is preferable to use explicit departure time choice models that factor trip tables, whether these are for daily trips or peak/off-peak trips. While simple and easy to use, the fixed link factor approach, which remains common in practice, ignores important factors that can influence peaking characteristics, such as the level of traffic congestion in the corridor, peak period pricing, and the diversity of housing and employment at the trip origins and destinations. It appears very difficult to account for these factors with any type of link-specific peaking factors, making trip table factoring the currently preferred method for departure time choice estimation within the four-step process.

In general, when congestion delay in a corridor increases, travelers shift more of their trips to the shoulders of the peak. Fixed factors can overestimate peak hour congestion and delay by being insensitive to the elasticity in departure time choice.

Demographic heterogeneity in housing and employment appears to also have an effect on peaking. People traveling to and from higher-density mixed-use areas tend to spread their trips more across the 24 hours of the day than people traveling to and from relatively homogeneous campus-style suburban employment centers or new, automobile-oriented low-density suburban subdivisions.[3]

Peak period pricing, in a variety of forms, can have a powerful effect on peaking behavior. The Dulles Toll Road, in Fairfax, Virginia, for example, is free for HOVs but a toll road for SOVs, and has induced changes in both automobile occupancy and departure time choice for automobile travelers in this corridor. Singapore's central area pricing system, which allows free entry into the CBD between 7 AM and 10 AM only for HOVs (of four or more persons) while charging a substantial fee for SOVs resulted in major mode and temporal shifts in travel behavior. Several cities in Sweden and Norway, including Stockholm, are now implementing area pricing with positive effects and represent this in their travel demand models.

These relationships can be represented by way of several different modeling approaches in the "four-step model," in what could be described as a "fifth step" -- departure time choice. Trip length, the ratio between free-flow and congested travel times for origin-destination pairs, and indicators of land use heterogeneity or density are key variables that should be considered in structuring departure time choice models, as in Montgomery County, Maryland. Where time-of-day pricing is a significant policy factor, it should be similarly introduced into model structures.

A typical current practice is to simulate trip generation and distribution on a daily basis and then factor to peak hour, using either link factors or trip table splitting factors. While departure time choice models can be validly applied to trip tables representing daily travel, there may be merit in doing trip generation and distribution by time of day. By generating trips separately for AM or PM peak periods, base period, and evening, trip chaining can be far more easily represented, as this varies greatly by time of day.

Departure time choice models should represent the greater elasticity of non-work trips to shift to the shoulders of the peak or out of the peak completely, and the lesser elasticity of work trips, both linked and non-linked to shift away from the peak hour.

The use of time-of-day trip generation and distribution models can improve the estimation of trip length and directionality of flows on networks. While daily trip generation and distribution models can be manipulated to produce reasonable directional peak hour flows, directionality and trip character become far more obvious in the analysis of time-of-day trip generation/distribution models.

The conventional approach lumps together trips from home to work and work to home as "home-based-work-trips," and must rely on attraction-to-production and production-to-attraction factors to account for directionality of flows at various times of day. Time-of-day trip generation/distribution models can produce estimates of AM and PM peak period home-to-work, work-to-home, and other trip purposes, both linked and unlinked. The trip distributions of these more discrete trip types by time-of-day vary widely. For example, home-to-work trips in the PM peak period tend to be shorter than home-to-work trips in the AM peak hour.

Modeling agencies need to take immediate steps to account for likely changes in the temporal distribution of trips by time of day under different scenarios examined as part of conformity analysis. Until empirically calibrated models are available, it may be preferable to use good planning judgment to introduce logical variations between scenarios from those produced using default fixed factors. At least such approaches can begin to illustrate the sensitivity of emissions and travel forecasts to policies which may modify the temporal distribution of travel.

IV. IMPROVING MODE CHOICE ANALYSIS

Mode choice models are used to analyze the share of trips between various origins and destinations which will be made by different travel modes. In typical MPO and state DOT practice, they are applied only to work trips, ignoring the choices travelers have (or might at some point in the future have) for making non-work trips by a means other than the automobile. Although some MPOs and DOTs have continued to use very crude non-network based mode choice models, even for regions where transit is as important as New York, a large number of agencies have recently developed logit mode choice models to separate transit from automobile trips, and sometimes for analysis of automobile occupancy and HOV (high occupancy vehicle) system use. These logit models typically account for relative travel time and cost of transit vs. automobile modes, along with automobile ownership, income, or other basic demographic characteristics of residents of travel zones. While these network-travel time based logit choice models represent an improvement over non-network based approaches and regression model techniques used in the past, in practice, they continue to display significant shortcomings for air quality analysis.

In most regional models, transit mode of access modeling remains very crude and subject to large errors in model applications.

8. Frequently, the share of access trips to transit made by walking vs. automobile park-and-ride or automobile "kiss-and-ride" (passenger drop-off) are exogenously estimated for base and future years, rather than forecast based on assumed changes in factors influencing access mode choice, such as changes in proximity of jobs and houses to transit stops, changes in pedestrian and bicycle access conditions, or capacity constraint or expansion of park-and-ride lots.
9. Automobile access travel times often do not represent congested highway travel times, and automobile access is usually not constrained by parking capacity.
10. Modeling transit access and the likelihood of walk and bicycle trips are areas where the variance in important factors influencing travel behavior between travel analysis zones are often less than the variance within zones, especially in lower density suburban areas which are typically represented with very large zones. Current models are insensitive to changes in the proximity of jobs and houses to transit and to convenience retail thus unable to capture many key effects of alternative transportation/land use scenarios.
11. Current models generally neglect walk and bicycle travel completely, and hence pay no attention to factors which condition the friendliness of the environment for walking and cycling. Incorporating such factors in the modeling process can improve model performance and support the examination of alternative transportation and land use scenarios in which non-motorized modes are made once again viable choices for a wide range of short trips and transit access trips.
12. Automobile ownership is one of the most sensitive inputs to mode choice models, but current models often extrapolate automobile ownership into the future using crude trend analysis. Alternative transportation and land use policies can be anticipated to influence household automobile ownership, in turn altering emissions. More policy sensitive automobile ownership models should be developed as soon as possible, with sensitivity to changes in transit accessibility, parking cost and availability, pedestrian friendliness and accessibility to convenience retail, and the overall cost of automobile use and ownership.

1. Improving Application of Current Mode Choice Models. In the immediate future, changes can often be made in application procedures of even current deficient models to begin to account for differences between alternative transportation/land use scenarios related to transit access characteristics. This is an important change to make in testing alternative long range plans as part of conformity analysis, and will frequently need to be complemented with the use of other techniques and adjustments to capture other important effects, such as non-modeled non-work travel behavior changes.

Specific procedures will vary from region to region, depending on the characteristics of the models and assumptions used in their base year estimation. However, an example drawn from the model used by the Metropolitan Washington Council of Governments (MWCOG) will illustrate the principles involved.

The MWCOG work trip logit mode choice model in use in 1992 was calibrated on 1980 Census journey-to-work data in 1985 and relies on travel time, travel cost, and household automobile ownership to estimate zone-to-zone mode share for automobile and transit. The share of access trips from an origin zone made by walk-connected transit access is an exogenous input variable, varying from 0 to 100%. For base year calibration, it was assumed that the average walk access time for those travelers who access transit by walking would be either 2, 3, or 5 minutes, depending mostly on proximity to the Washington, DC CBD and, in parallel, the zone size. The quality of walk access trips are not an input factor, which has been found to cause the model to overestimate transit use to suburban employment centers, although the model performs reasonably well at the regional level, where the bulk of home-to-work transit trips are destined for the central business district.[4] Extensive area-to-area adjustment factors are needed to improve the model's fit to observed data.

While this model has significant limitations, in the absence of a better model, it can be adapted to test alternative transportation and land use scenarios by making adjustments to some of the input factors. In general, there should be no changes made to base year calibration data regarding zone-level walk-access-to-transit share or average walk travel time to transit unless the change reflects an explicit change in the amount and pattern of land use or transit in the zone. These variables become the key to reflecting in the modeling system at least some of the effects of more clustered or more sprawled development choices (through modifying the input data on the share of households and jobs within walking distance of transit in each zone) and of improvements or degradation of the quality of the pedestrian environment within the walk-to-transit service area of the zone (through modifying the input data on the average user-perceived walk-to-transit access travel time).

It would be plausible to modify both of these input factors for long-range scenarios envisioning major improvements in pedestrian friendliness (for example, by making it easier to cross streets near transit stops or stations, retrofitting sidewalks where they are lacking along transit routes, or introducing traffic calming in transit station areas) combined with the concentration of most new zonal development within walking distance of transit -- increasing the assumed share of activities within walking distance and reducing the assumed access time (since people do not put so much weight on time spent in a pleasant environment as in an unpleasant one). Particularly for large suburban zones, it would be also be plausible to modify both of these input factors for long-range scenarios envisioning a concentration on highway investment, little investment in sidewalks, bus stop shelters, or other pedestrian amenities, and a low-density, homogeneous-use, automobile-oriented land development pattern -- reducing the assumed share of activities within walking distance of transit and increasing the assumed access time (since only transit dependent riders would use the service).

2. Representing Automobile Access to Transit. Most models do not reflect actual congested travel times from zones to park-and-ride lots or other points of automobile access to transit, nor do they consider parking capacity constraints in estimating automobile park-and-ride lot demand. Both of these elements can be addressed within the current modeling software in at least a first order fashion with low overhead costs using appropriate computer programs, as has been demonstrated by the Montgomery County Planning Department in their TRAVEL 2 model. Congested highway skim times from zones to park-and-ride lots can be estimated for various scenarios and used in mode choice analysis. For each zone-to-zone pair, a limited set of reasonable park-and-ride lot choices can be estimated dynamically and then used with a capacity constrained assignment process to better consider how the market area of park-and-ride lots will change over time as areas develop, and new park-and-ride lot choices become available or oversubscribed, and in response to changes in transit services to park-and-ride lots.[5]

3. Modeling Walk-Access to Transit and Non-Motorized Travel Options. Mode share models are usually quite sensitive to changes in access and egress travel time. Current models are often unable to measure and analyze such basic questions as: How many jobs and houses are within walking distance of bus stops and transit stations? To what extent can workers or residents in this location accomplish their routine errands by foot?

Instead, crudely estimated zonal average access and egress times to and from transit are usually coded in a quasi-arbitrary manner. They are usually assumed to be equal for access and egress for a given zone, although there is evidence that people are willing to walk farther to transit at the home end than from it at the destination end. The use of a single value for transit walk access travel time for a zone masks a wide range of variations in pedestrian accessibility to transit which exist within each zone.

While these methods are crude but effective in urban centers where zone sizes are small, in suburban areas where zone sizes are usually quite large, they become nearly absurd in their level of abstraction. Three strategies can aid in addressing these problems:

1. Use Geographic Information Systems (GIS) or other tools and methods to better estimate indicators of the actual share of jobs and households within various access distances of transit in each zone and use this data to stratify mode choice analysis by access distance from transit.
2. Adopt new more disaggregate traffic analysis zone systems focused on transit nodes or major bus service corridors, rather than defining zones solely by major roads. Zone and network detailing is most essential in areas where transit use is or may be expected to become significant and in major growth areas. Census blocks and TIGER networks are a potential foundation for low-cost development of finer grain zone and network systems in any community in the U.S.
3. Rather than working at the zone level, perform mode choice analysis (or general travel demand analysis) at the household level using measured data on access distance to transit, using microsimulation techniques. Use a GIS and various survey data to expand microsimulated households to represent the universe of households for regional analysis.

Geographic Information Systems (GIS) are the key to efficient and cost-effective analysis of the proximity of jobs and houses to each other and to public transportation and daily services. It is important to recognize that the level of GIS needed for such analysis does not carry the high price seen on high precision engineering and public works inventory GIS systems used for facilities management. What is required is a low to mid-level planning-oriented GIS, capable of precision to the order of 100-200 feet (30-60 meters), not several feet (1-2 meters). In many regions, such tools are already available or are under development. In many regions, an adequate system for this type of application can be developed within the span of a single year, adapting existing off-the-shelf Census TIGER files (which contain geo-referenced information on streets and street addresses for all areas of the U.S.) and local or state tax assessor property parcel records, driver license files, and commercial and multi-family residential property record lists. GIS can also enable the assembly of new databases on the location of transit stops, sidewalks, bicycle facilities, and other factors influencing pedestrian, bicycle, and transit friendliness.[6] Bus stop and sidewalk location data can be readily tracked using the TIGER file as a reference. Whatever the data structure used, be it TIGER or some other address referencing topological file, maintenance and updating of the files is important to ensure an effective planning tool.

4. Sensitivity to Variations in Pedestrian and Bicycle Friendliness. Mode choice and other elements of travel behavior are conditioned significantly not only by the proximity of land uses to each other and to the transit network, but also to the quality of the environment for walking and bicycling. However, current transportation models, with a few exceptions, have no way of representing the quality of the non-motorized travel environment or the actual or potential use of non-motorized modes as a substitute for motorized travel.

The wide variation in pedestrian and bicycle use across America suggests that walking and bicycling are currently latent and suppressed travel modes in many communities, which might be revitalized under appropriate conditions.[7] Such revitalization could have a significant effect on air pollution, since vehicle trip starts (especially non-work trip starts) account for a far greater share of mobile source emissions in most regions than VMT-related running emissions (or work-trip emissions) and since trip start related emissions continue to grow as a share of total emissions (representing, for example, an estimated 61% of emissions in the Washington, DC region in 1990 and 70% of mobile source emissions in 1996[8]).

It is highly desirable to include explicit representation of walk and bicycle modes in the travel demand analysis process, along with TCMs and infrastructure investment and management decisions that could increase the use of walking and cycling. This representation should take into account the potential for pedestrian and bicycle improvements to increase walk and bike mode shares, and the share of trips made by combining walking and cycling with public transportation. Development of inventories of sidewalks, bicycle facilities, and streets with slow traffic speeds and low volumes friendly to cyclists and pedestrians is an important first step towards bringing these modes of transportation into the travel supply and demand analysis system. Without such inventories, TCMs intended to encourage cycling and walking cannot be properly prioritized for cost-effective transportation investments.

There is a great need for basic data collection related to walking and cycling. As a first step, bicycle and pedestrian friendliness should be incorporated into current model structures using qualitative indices, as has been done for several years in Montgomery County, Maryland, with its "Transit Serviceability Index/Index of Pedestrian and Bicycle Friendliness."[9] This approach gives a score to each traffic zone based on the extent and interconnectedness of sidewalks and bicycle facilities and traffic calmed or restricted areas, the density and mix of land use, the extent of building set-backs from the street, and the availability of bus stop shelters. Similar indices can be used as part of logit mode choice and other models as a surrogate for otherwise missing information on the character of the transportation supply system for pedestrians and cyclists. This approach could be used both in short-term pivot point analysis techniques and in more comprehensive regional models. Portland, Oregon's METRO, working with Cambridge Systematics and 1000 Friends of Oregon, has recently developed a similar mode choice model incorporating a pedestrian-friendliness indicator.[10]

Research in the Washington, DC region indicate that travel time and cost alone do not appear to be sufficient to explain variations in transit use. Pedestrian and bicycle friendliness appears to have a significant effect on how far people are willing to walk (or cycle) to reach public transportation. While few people will walk 10 minutes to a bus stop if that walk is along busy roads without sidewalks and where there is no bus stop shelter, more people will consider walking the same distance if there is a safe and comfortable place to walk, the opportunity to stop en route at shops to attend to errands, and shelter at the stop.

This area needs particular attention for research and development. There is significant promise for improved modeling methods to treat walk and bicycle transportation within the next several years. These will likely rely on GIS for inventories of sidewalks, street widths, traffic speeds and volumes, median strips and safety islands, locations of free right turns, bicycle paths and lanes, streetscape continuity, crime levels, and other factors influencing the friendliness of an area for walking and cycling. Table 4 illustrates some of the factors which should be considered in developing new models reflecting pedestrian friendliness and Table 5 shows comparable factors that may relate to bicycle friendliness. New models can be calibrated with disaggregate travel survey data and exploring the statistical significance of these various factors in explaining variations in travel behavior. It would be most useful to assemble multi-city or even multi-country data using similar measurement systems and surveys for a richer examination of how these and other cultural, pricing, and accessibility factors influence travel behavior.

Table 4: Factors That May Relate to Pedestrian Friendliness

- ratio of sidewalk to street miles
- sidewalk connectivity
- share of length of main roads with sidewalks
- street crossing difficulty index (e.g. as a function of the traffic volume, speed, number of lanes without a median, frequency of pedestrian-signalized crossings)
- average sidewalk width
- share of sidewalks with buffers between sidewalk and street
- historic pedestrian accidents and fatalities
- proximity to pedestrian only streets
- incidence of street crime in neighborhoods
- topography

Table 5: Factors That May Relate to Bicycle Friendliness

- ratio of bikeway to street miles
- bikeway or bike lane connectivity
- share of length of main roads with bikeways/bikelanes
- street difficulty index (e.g. as a function of the traffic volume, speed, lane width, and pavement condition, aggregated for zones and for network connectivity estimation)
- intersection difficulty index (e.g. similar to index for pedestrians)

- topography (such as the length of links along the likely paths between origins and destinations with grades exceeding 5%).

Walk and bicycle transportation should be accounted for not only in mode choice but also in trip generation and distribution. It appears likely that when people are offered a high quality pedestrian and cycling environment and become reliant on these modes for a significant share of their travel, their destination choice, especially for non-work travel, is more strongly influenced by their pedestrian, bicycle, and transit accessibility than by their automobile accessibility.

5. Automobile Ownership Sensitivity. Automobile ownership has been found in numerous studies to have a major effect on mode choice and trip-making. The sound treatment of automobile ownership or availability as an important factor in travel demand estimation is an important area for model development.

Automobile ownership forecasting models should be sensitive to the potential for lagged negative effects of significant increases in transit, walk, and bicycle accessibility on household automobile ownership which is suggested by evidence from a number of communities. Further longitudinal and cross-sectional empirical research should be undertaken in a number of regions to develop automobile ownership models sensitive to such potentials, as well as to other policy and pricing factors that may influence automobile ownership.

Emissions models assumptions about motor vehicle fleet mix should incorporate sensitivity to changes in taxes and fees that are keyed to emissions or fuel use, such as the "feebates" proposed by a number of analysts, which would penalize purchasers or owners of high emission vehicles while rewarding purchasers or owners of low emission vehicles. Models which are sensitive to the type of motor vehicle and its resultant emissions level are needed, particularly in light of the introduction of zero emission vehicles with substantially different operating characteristics than conventional gasoline vehicles. The use of stated preference surveys and microsimulation techniques offer substantial promise in this area.

V. IMPROVING NETWORK ASSIGNMENT MODELS

Network assignment models are a part of travel demand analysis that is often done mechanically, using canned routines. While equilibrium network assignment techniques have come into widespread use and offer superior performance over iterative or incremental capacity-constrained assignments, there are still weaknesses in current practice which require further work to meet appropriate standards for air quality analysis.

13. Networks remain overly coarse in many regional models and fail to differentiate between areas where there are a grid of interconnected streets not represented in the modeled network and areas where the streets not represented in the modeled network indeed fail to connect meaningfully with each other. Off-network emissions estimation remains a problem without GIS TIGER file based street inventories.

14. Highway capacity and delay continue to be represented in most regional models by link-based functions which cannot properly reflect the effects of intersection congestion and delay. This is an important oversimplification which affects emissions estimates which are dependent on the accurate estimation of travel time and delay.

1. Increasing the Level of Network and Zone Detail. The appropriate level of network detail in conventional transportation models is a function of the level of zone detail. Course zone systems with large zones are consistent with networks that represent only large roads. Fine-grain zone systems are consistent with networks that offer rich detail, including many small roads and transit lines.

Regional models typically are not able to differentiate between neighborhoods where the non-modeled road network consists of interconnected grids of streets and neighborhoods where the non-modeled road network consists of cul-de-sacs and other disconnected streets which provide no parallel routes for short trips. Recent research by Walter Kulash suggests that neo-traditional interconnected street systems provide much greater network capacity, particularly by reducing intersection critical lane volumes, than is found in the cul-de-sac and major arterial street systems so common in recent suburban subdivision planning. Such differences need to be reflected in coding networks, or through explicit representation of intersection turning movement capacity and delay, with finer grain networks. Representation of all streets that carry through traffic is important to representing network connectivity and alternative paths within networks, as well as developing regional inventories of mobile sources. Streets that carry public transportation similarly should be included in regional networks to permit proximity analysis of jobs and housing to transit, if possible, using inventories of transit stops maintained within a Geographic Information System (GIS).

Sensitivity to variations in proximity and accessibility of jobs and housing to each other and to public transportation is most easily represented using finer grain zone systems than are typically used by MPOs. The current representation of newer, fast-growing suburban areas is typically most deficient, with the use of overly large zones. The use of large zones makes estimation of walk and bicycle travel potential highly problematic, given the short average trip lengths of these modes. Although the use of smaller zones requires larger trip tables and longer model run times, computing power and cost-effectiveness are breaking many old barriers to greater disaggregation. Microsimulation approaches promise to further demolish these barriers as conventional trip table manipulation for travel demand analysis is replaced by the simulation of individual trip records, which can later be expanded to represent the larger population of travelers.

Emissions analysis should consider also intrazonal trips. Reduction in the average size of traffic zones will reduce the number of intrazonal trips while making it possible to examine TCMs that divert some intrazonal trips from automobile to non-polluting modes, such as walk and bicycle. An initial first step would be to construct a GIS-based inventory of emissions using a regional TIGER file as the starting data base, as has been proposed for the New York region by Brian Ketcham of Konheim and Ketcham Associates.

2. Separating Intersection and Link Capacity and Delay. As noted above, the explicit representation of intersection capacity and delay separate from link capacity and delay is highly desirable. A very large share of arterial vehicle delay is caused by intersections and turning movement conflicts, rather than by link capacity saturation. Montgomery County, Maryland, and other agencies have developed a method for explicitly separating these components of the highway network for equilibrium network assignment, at least for major intersections in the system.

This may impose challenging requirements for larger databases and additional computer time for network assignments, especially in large regions. However, it can produce much more representative network loadings and representation of delay, acceleration/ deceleration cycles, and speeds, which are important for emissions analysis and forecasting. It may be expedient to develop surrogate representations of these factors in more aggregate network models for alternatives testing, but the development of more comprehensive base inventories and models that account for all these factors is important for improving emissions analysis.

VI. Ensuring Sensitivity of Models to Alternative Land Use Scenarios

Land use inputs to current MPO and state DOT transportation models are usually exogenous forecasts prepared with little or no consideration of transportation policy, planned future investments, environmental constraints on growth, or the potential for significant changes in growth trends from recent decades. The use of fixed land use forecasts, especially for long range planning, will be subject to increased challenge in the future as incompatable with good planning practice, the Clean Air Act Amendments of 1990, ISTEA's fifteen principles and general spirit, informed public participation, and common sense. There is no doubt that land use issues are highly sensitive and very political, or that they condition and constrain the kind of society we will live in for the remainder of our lives. For all of these reasons, alternative land use patterns and scenarios must be a part of future long-range planning in American communities.

Consistency of Land Use Forecasts with Investment Decisions and Pricing Policies. Conformity analysis should require a reasonable match between the assumed level of infrastructure investment, transportation pricing policies, fiscal capability to deliver the planned infrastructure, and the level and location of forecast growth. Large transportation infrastructure investments are generally not fiscally supportable without some degree of accompanying growth that makes use of these investments or significant user fees to finance costs.

The use of fixed land use forecasts with widely varying transportation investment programs, as was the practice in the initial round of interim conformity analysis in 1991, is illogical and artificial, contributing little to identification of sound transportation strategies. More ambitious investment programs should be evaluated assuming a faster rate of growth in jobs and housing; no-build investment programs should be evaluated assuming a slower rate of growth. In other words, within limits, growth and investment should be coupled.

Significant changes in transportation pricing can also have some influence on growth patterns. Extensive subsidies for automobile use have contributed to growing trip lengths and sprawl over time; higher costs for single occupant vehicles (SOV) use combined with expanded non-SOV transportation options can be expected to favor more clustered growth and reduced average SOV trip lengths over time.

Precisely how these linkages can best be achieved and how specific transportation investments or pricing changes influence job and housing location is an area requiring further research and model development. However, in the short-term, Delphi approaches for modification of current land use forecasts to make them consistent with transportation scenarios should be used unless land use forecasting models are available in a region. The results of such work should be subject to a reasonableness test by the larger community. Even where land use forecasting models are available, the reasonableness of their sensitivity to changes in these input factors should be examined.

Consideration of changes in accessibility on land development market forces. This can be accomplished in the short term by ensuring that alternative land use forecasts are prepared for air quality conformity analysis based on different transportation investment, operations, and policy scenarios. As a minimum, land use forecasts should vary with alternative transportation scenarios. Areas with expanded road or transit capacity should be evaluated for their potential for added growth due to improved accessibility.

This can be accomplished using linked land use-transportation models, such as ITLUP, MEPLAN, or POLIS, which require significant investment and data for calibration. Or it can be accomplished through more qualitative assessment, using Delphi techniques with local planners, land use experts, and citizens, taking into account past and anticipated trends and policies. Regardless of the process used, information is needed on recent and current land use patterns and change, the location of already approved development, the current zoning limitations, and potentials for redevelopment and zoning change, all on a small area (traffic zone) basis. Current accessibility patterns and potential changes under various transportation scenarios, including consideration of anticipated congestion, must become a significant factor in land use forecasting processes used to support transportation/air quality conformity.

Regions that fail in meeting conformity targets and need to implement trip and VMT reduction will be required to evaluate alternative transportation scenarios to those used in their earlier conformity analysis. These alternative scenarios should reflect changes in land use forecasts consistent with changes in transportation pricing, investments, and policy. Where significant transit investments are being evaluated, local land use and zoning policies should be evaluated for potential change to encourage more dense clustered development near transit nodes and downzoning in low-density automobile dependent areas. Where linked land use-transportation models are available, such potential changes in zoning should be evaluated for their potential synergistic interaction with changes in transit and highway accessibility and pricing.

VII. REPRESENTING TRANSPORTATION DEMAND MANAGEMENT

Representing Transportation Demand Management (TDM). TDM encompasses a very wide variety of transportation strategies, from pricing changes to marketing and encouragement programs and priority treatment of desired modes. Representing TDM in TPLUAQ modeling is a substantial challenge, given the complex details of many TDM programs, site specific application of programs, and the sensitivity of program effectiveness to the surrounding context in which it is implemented.

There are a variety of ways to attempt to represent TDM measures in the modeling process, but the most promising best practices to date have involved pivot point modeling, as is the approach of the COMSIS TDM evaluation software. For individual activity centers, this approach is quite useful. For entire metropolitan areas, it may be desirable in the mid-term to try to integrate the factors represented in such software into region-wide mode choice models. This would, however, often require additional data collection and revalidation or recalibration of mode choice models.

The COMSIS TDM model takes an approach that may be most helpful in providing required policy sensitivity in the short-term at low cost, while data collection and model development proceed towards creation of refined new TPLUAQ models for mid-term application.

At a regional level, the TRIPS model, developed from MTC data by Greg Harvey, offers a useful set of tools for adjusting regional models to better account for feedback of pricing and accessibility changes on trip generation, distribution, and mode choice. This disaggregate model is being used in the Los Angeles region by SCAG for evaluation of policy changes.

Many current regional models are insensitive to the income-related effects of major pricing policy changes. The TRIPS model provides a useful and potentially transferable framework for better incorporating these factors in regional conformity analysis in the short-term, using pivot point analysis methods.

Pricing is the most important tool for short-term management of transportation demand to meet air quality standards. It should be a high priority to increase the ability of travel demand models to simulate the travel behavior effects of transportation pricing changes, including parking charges, changes in commuter subsidies, tolls, area-pricing systems, transit pricing and fare instrument structures, and vehicle ownership and operation costs.

VIII. EMISSION MODEL SENSITIVITY TO TRANSPORTATION CHANGES

Emission Model Sensitivity to Transportation Changes. The separate analysis of air pollution emissions related to Vehicle Miles of Travel (VMT running emissions), the number of trips (relating to cold start and hot soak emissions), and the number of motor vehicles (relating to diurnal emissions) is also highly desirable. The frequent practice of evaluating emissions as if they were related only to VMT by speed range is unacceptable and can lead to major errors in estimating the emissions impacts of TCMs. Running emissions account for less than half of all emissions, with the remainder attributable to trip starts and evaporative emissions.[11]

For example, by switching longer automobile driver trips to park-and-ride, there may be a significant reduction in VMT but only a very small reduction in emissions, because the reduction in running emissions is small compared to the remaining cold start and hot soak emissions. On the other hand, by shifting short automobile trips to the bicycle or walking, there may be an insignificant reduction in VMT but a substantial reduction in emissions, through elimination of cold start and hot soak emissions.[12]

More equal attention should be given to running, trip, and diurnal emissions in the evaluation of TCMs by ensuring that models are sensitive to policies that can affect each of these components of automobile-related pollution sources.

At the same time, VMT-based emissions analysis should be sensitive to several factors not well accounted for in much initial conformity analysis work. These include --

- Many transportation models cap free-flow speeds on roads at the speed limit, even though real speeds often exceed the speed limit and enter a speed region above 55 mph, where emission rates per VMT increase, rather than decrease with speed. Thus, if HOV lanes are open to general traffic in non-peak periods, this may offset some of the emission reductions of the peak-period HOV facility by stimulating faster off-peak travel in congested corridors.
- Acceleration at intersections and highway ramps often account for very high emission rates for short periods of time, but are not accounted for by the average link speed approach used for emissions analysis.
- Traffic calming measures that slow down automobile traffic in residential or commercial areas can provide major improvement in the pedestrian and cyclist environment and reduce the number of trips (especially short trips) made by automobile. Conventional analysis approaches may reflect such changes as causing increased emissions due to lower average automobile speeds, but are insensitive to the reductions in high-emissions accelerations and cold starts/hot soaks that may be induced by traffic calming measures.

IX. Developing a Plan for Model and Information System Improvement

Many metropolitan regions have had to undertake air quality conformity analysis with transportation models not well suited to the task because they lack sensitivity to many key factors influencing travel demand. Short time frames make possible only minor improvement of the models for near-term deadlines. More fundamental improvement of models through major respecification generally requires a several year time frame to allow for data collection, analysis, model development, and validation. Thus, many regions are undertaking multi-year programs for model enhancement, in parallel with model applications. The Washington, DC, Transportation Planning Board's Travel Forecasting Subcommittee, for example, in 1990-91 developed a five-year plan for improving travel forecasting and information systems which is now giving guidance to the region's efforts in this area.[13]

Short-term quick response measures are needed to develop techniques that can be used in the near-term to enhance policy sensitivity, such as pivot point models and the use of qualitative indices. Factors to be considered include the effects of pedestrian and bicycle friendly vs. automobile oriented urban design, clustered mixed-use development within walking distance of transit nodes, parking pricing, commuter subsidy, and other policy changes, and the development of alternative land use growth scenarios consistent with automobile vs. transit oriented development patterns. Portland, Oregon's METRO is developing such methods as part of a cooperative project with the non-profit group, 1000 Friends of Oregon, in an innovative project, "Making the Land Use, Transportation, Air Quality Connection."

X. CONCLUSIONS

To meet the standards of the Clean Air Act Amendments of 1990, major improvements will be needed in the methods used to analyze the relationships between transportation, pricing, land use, and air quality (TPLUAQ) in metropolitan areas. Current methods for analysis of these relationships in most regions in non-compliance with the CAA are grossly inadequate to the requirements of that Act. Funding for TPLUAQ assessment, monitoring, and analysis must sharply increase in the immediate future.

What today represents "best practices" in modeling, will likely undergo significant further upgrading as rapid advances are made in research and modeling techniques in response to reduced costs of computing power, renewed survey activity, and the linking of GIS and conventional modeling methods.

Potentially superior alternate frameworks for TPLUAQ modeling need further exploration and development in the next several years. Particular attention should be given to research and development work based on activity analysis, time-budget theory, microsimulation techniques, and improved use of discrete choice analysis. The development of more operationally-oriented Intelligent Vehicle and Highway System (IVHS) short-term real-time traffic forecasting systems needs to be complemented by accelerated work on long-term planning and analysis systems. While such techniques offer substantial promise, these new models will require

The conventional four-step process (trip generation/trip distribution/mode choice/network assignment) should be adapted in the next few years to incorporate new techniques for refined spatial analysis, proximity planning, and representation of the pedestrian and cycling environment made possible by linking Geographic Information Systems (GIS) with TPLUAQ planning and forecasting models. The number and share of jobs and houses within walking distance of transit and local services and the quality of the pedestrian environment together appear to have a major influence on transit use and access mode choice, and likely influence trip generation, distribution, and the degree of trip chaining. GIS can also provide a framework for development of more comprehensive inventories of parking supply, parking cost, and employer-based commuter subsidies, which have substantial potential for influencing short-term changes

Accelerated data collection and monitoring, model development, will be especially crucial in communities across the U.S. which now fail to meet air quality standards. As it will take at least several years of increased funding and effort in this area to put into place appropriate analytic tools and information systems in most communities, parallel short-term efforts to enhance the policy sensitivity of existing tools will be essential to support interim transportation-air quality conformity analysis.

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